Cost and Performance Report

Pit 6 Landfill Operable Unit

Lawrence Livermore National Laboratory Site 300

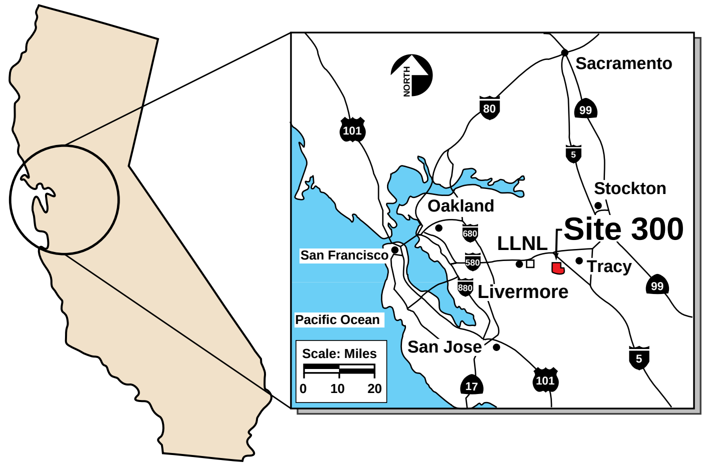
December 1997

UCRL-AR-128480

U.S. DEPARTMENT OF ENERGY

1. SUMMARY

From 1964 to 1973, approximately 1,900 cubic yards of waste was placed in nine unlined debris trenches and animal pits at the Pit 6 Landfill at Lawrence Livermore National Laboratory Site 300. The material buried included laboratory and shop debris, and biomedical waste. Contaminants potentially associated with the waste include organic solvents, radionuclides, PCBs, and metals. Plumes of volatile organic compounds (VOCs) and tritium in ground water emanate from the landfill. The primary VOC released is trichloroethene (TCE). In 1997, a 2.4-acre engineered cap was constructed over the landfill as a CERCLA removal action, isolating the waste from rain water or surface water infiltration and eliminating safety concerns related to potential subsidence. The total cost of constructing the landfill cap was about $1,500,000. Selectively substituting geosynthetic for natural materials saved over $500,000. Total past and projected project costs are approximately $4,100,000.



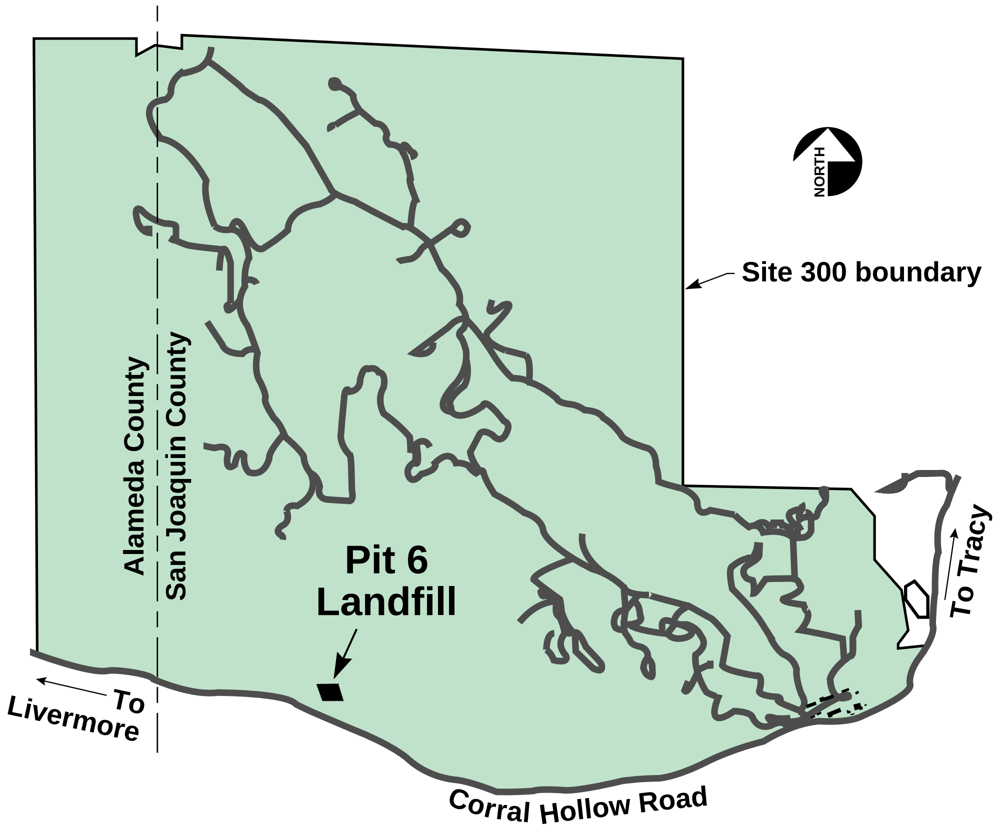
Location of LLNL Site 300.

Pit 6 Landfill and overlying rifle range prior to cap construction; view looking south (May 1997).

2. SITE INFORMATION

Identifying Information

- Facility: Lawrence Livermore National Laboratory (LLNL) Site 300.
- Operable Unit: Pit 6 Landfill (OU 3).
- Regulatory Drivers: Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), Site 300 Federal Facility Agreement.
- Type of Action: Landfill capping and ground water monitoring as a CERCLA non-time-critical removal action.
- Period of Operation: Capping completed in September 1997. Post-closure maintenance and monitoring will continue.



Location of the Pit 6 Landfill at LLNL Site 300.

Technology Application

A cap has been constructed over the Pit 6 Landfill to: (1) isolate the buried waste from rain water and/or surface water infiltration, (2) divert surface water from the covered area, (3) eliminate safety hazards from subsidence into void spaces in the buried waste, (4) mitigate risk from potential inhalation of vapors from the subsurface, and (5) reduce ground water recharge near the contaminant pumes.

Site Background

LLNL Site 300 is a DOE experimental test facility located in the rugged, semiarid Altamont Hills east of Livermore, California. The Pit 6 Landfill lies near the southern boundary of Site 300 along Corral Hollow Road, and is situated on an alluvial terrace about 40 feet above the Corral Hollow Creek flood plain. The landfill received about 1,900 yd^3 of material from LLNL and Lawrence Berkeley Laboratory from 1964 to 1973. Waste was placed in three debris trenches and six smaller animal pits. A disposal log was kept by LLNL, but is not sufficiently detailed to permit full characterization of the waste.

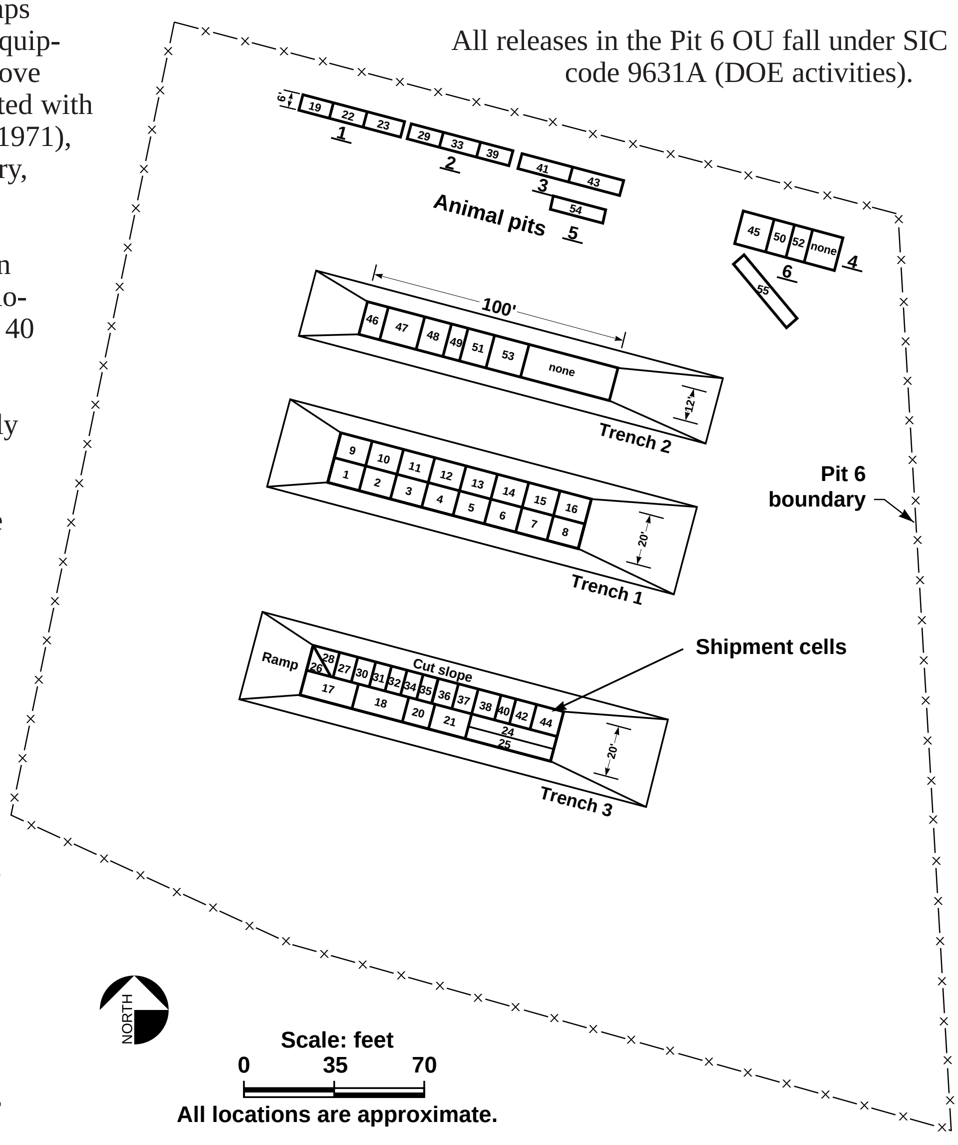
Laboratory and shop debris was placed in trenches 1, 2, and 3, located in the central part of the landfill. Each trench was about 100 feet long, 12 to 20 feet wide, and 10 feet deep. Debris was placed in 42 shipment cells, with a total volume of approximately 1,750 yd^3. Records indicate that the trench waste includes capacitors, drums and tanks, compressed gas cylinders, lamps and ignition tubes, shop and laboratory equipment and waste, ductwork, filters, and glove boxes. Contaminants potentially associated with the debris include uranium (exhumed in 1971), thorium, beryllium, VOCs, PCBs, mercury, and cutting oil.

The six animal pits located in the northern part of the landfill received waste from biomedical experiments. Each pit was 20 to 40 feet long, 9 feet wide, and about 16 feet deep. Waste was placed in 13 shipment cells, with a total volume of approximately 150 yd^3. The waste consisted of animal carcasses, blood, milk, feces, and urine. Records indicate that up to 42 radioactive isotopes were present in the waste, with an estimated total activity at time of burial of 0.7 to 2.1 Curies (Ci). This includes about 0.5 Ci of tritium buried in two shipment cells; 99.96% in cell 55 and 0.04% in cell 23. The half lives of the buried isotopes range from 12.8 hours to 30 years. Some of the decay products of the original isotopes have longer half lives, but the activity of these daughter products is estimated to be below background. The total activity remaining in the animal pits after at least 24 years of burial is estimated to be 0.12 to 0.18 Ci.

After burial, all waste was covered with several feet of native soil. The landfill was not constructed with liners, containment structures, or leachate control systems. Due to safety considerations, no intrusive investigations of the buried material have been performed. A rifle range used for training exercises by LLNL was located directly over the landfill.

Documents prepared for the Pit 6 OU include the Site-Wide Remedial Investigation report (Webster-Scholten, 1994); a Feasibility Study (Devany et al., 1994), which was later redesignated as an Engineering Evaluation/Cost Analysis (EE/CA); an addendum to the EE/CA (Berry, 1996); and an Action Memorandum (Berry, 1997). A Post-Closure Plan is in preparation.

All releases in the Pit 6 OU fall under SIC code 9631A (DOE activities).



Pit 6 Landfill.

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3. MATRIX AND CONTAMINANT DESCRIPTION

Matrix Identification

Approximately 1,900 yd^3 of laboratory and shop debris and animal waste are buried in the Pit 6 Landfill. VOCs and tritium have been released contaminating ground water, soil, and bedrock.

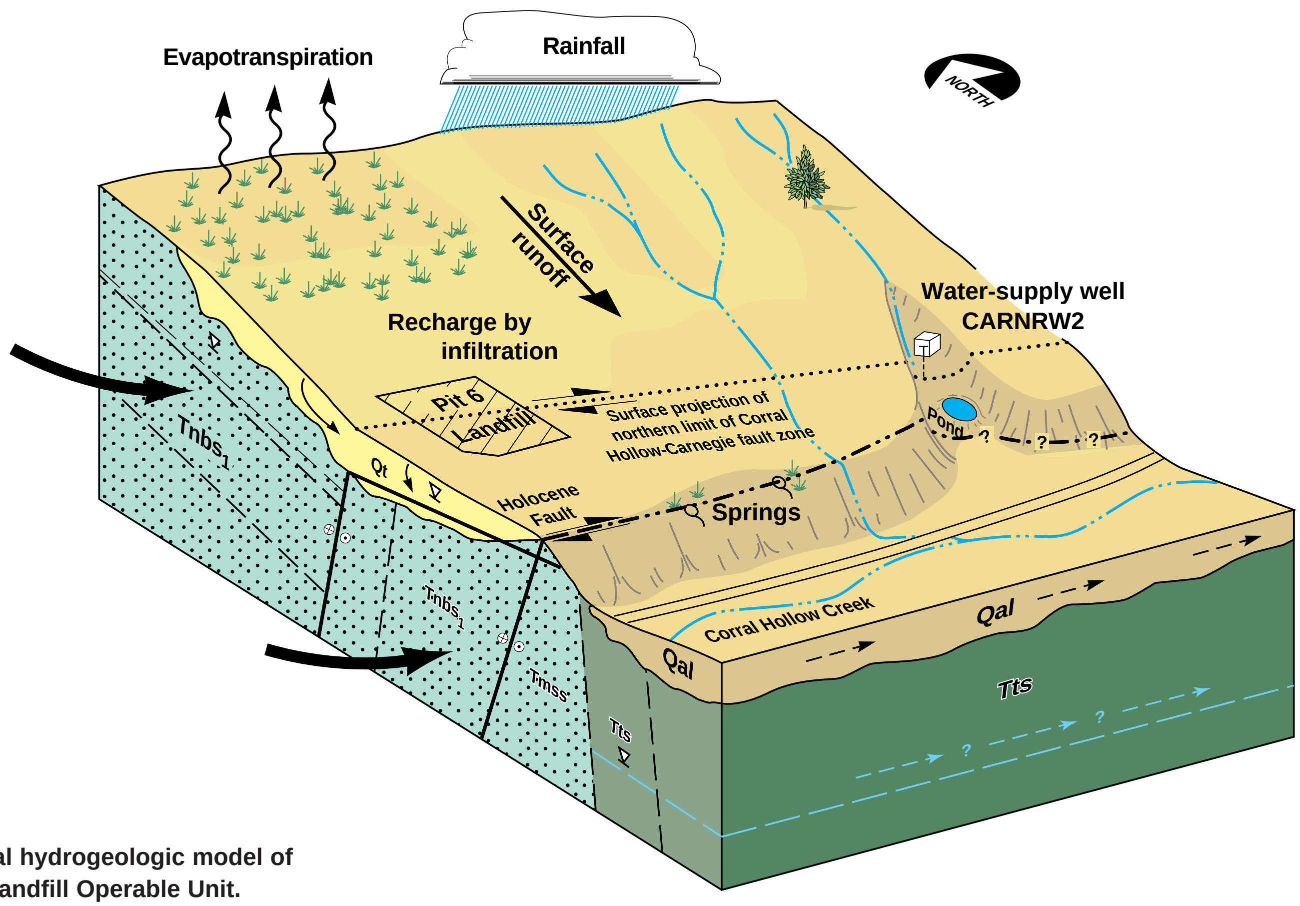
Hydrogeology

The Pit 6 Landfill is located on a Quaternary-age alluvial terrace up to 55 feet in thickness. The alluvium overlies Tertiary-age sedimentary bedrock. The landfill is situated along the northern limit of the Corral Hollow-Carnegie Fault Zone. North of the fault zone, bedrock dips southward at 5 to 20 degrees. Within the fault zone, bedrock is nearly vertical to overturned. Evidence of Holocene activity has been observed along a fault strand located about 150 feet south of the landfill.

Ground water is about 30 to 50 feet below ground surface beneath the landfill. While ground water elevations can vary seasonally by several feet, the water table remains at least 15 feet below the bottom of the buried waste. Shallow, unconfined ground water flows to the southeast at an estimated average rate of 30 to 70 feet per year.

During the winter rainy season, ground water has been observed flowing intermittently from springs along the edge of the alluvial terrace. These springs have been dry for the past several years as water levels declined.

Hydrogeology (cont.)



Conceptual hydrogeologic model of the Pit 6 Landfill Operable Unit.

Contaminant Physical Properties

Physical properties of VOCs released from the Pit 6 Landfill.

Contaminant	Vapor pressure (mm Hg)	Henry's Law constant (atm-m^3/mol)	Density constant (g/cm^3)	Water solubility (mg/L)	K_{ow}	K_{oc}
Chloroform	160	3.23E-03	1.4890	8.00E+03	79.43	43.65
cis-1,2-Dichloroethene	208	7.58E-03	1.2837	3.50E+03	5.01	49.00
Tetrachloroethene	14	1.53E-02	1.6227	1.50E+02	398.11	263.03
Trichloroethene	58	9.10E-03	1.4642	1.10E+03	338.84	107.15

Vapor Pressure: The higher the vapor pressure, the more volatile.
Henry's Law Constant: Compounds with constants greater than 1E-3 readily volatilize from water.
Density: Compounds with a density greater than 1 have a tendency to sink (i.e., DNAPLs); compounds with a density less than 1 have a tendency to float (i.e., LNAPLs).
Water Solubility: Highly soluble chemicals can be rapidly leached from wastes and soils and are mobile in ground water; the higher the value, the higher the solubility.

Octanol-Water Partition Coefficient (K_{ow}): Used in estimating the sorption of organic compounds on soils (high K_{ow} tends to adsorb more easily).
Organic Carbon Partition Coefficient (K_{oc}): Indicates the capacity for an organic chemical to adsorb to soil because organic carbon is responsible for nearly all adsorption in most soils (the higher the value, the more it adsorbs).

Contaminant Physical Properties (cont.)

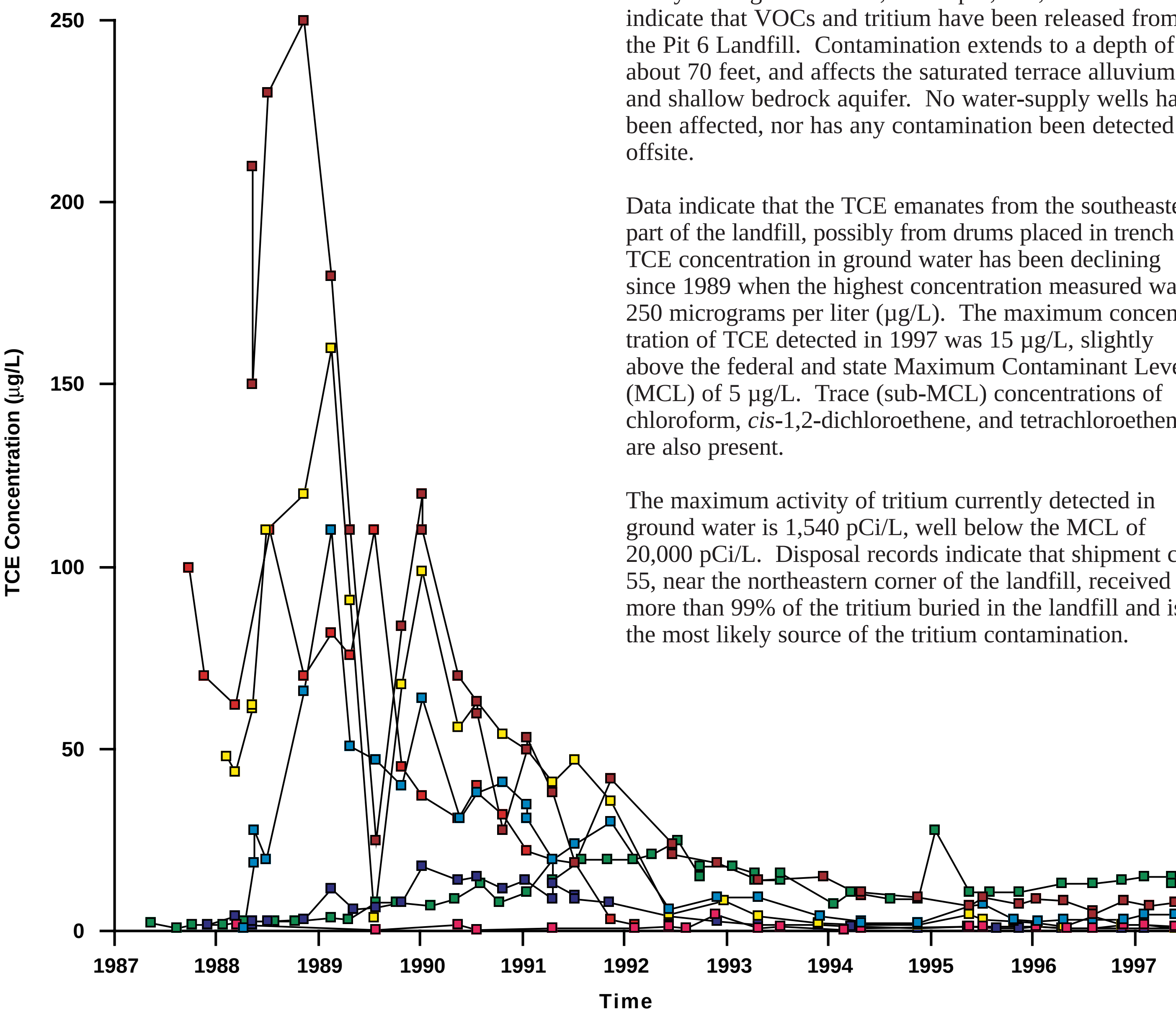
Tritium is the only radioactive isotope of hydrogen. It contains two neutrons in the nucleus, in addition to one proton that all hydrogen isotopes share. Thus, it has an atomic number of 1, an atomic weight (mass number) of 3, and is three times heavier than a hydrogen atom. Due to radioactive decay, tritium has a physical half-life of 12.26 years. It decays to a stable isotope of helium with the emission of a low-energy beta particle. Tritium concentration in ground water is typically expressed in units of radioactivity, or activity per unit volume as picoCuries per liter (pCi/L).

Nature and Extent of Contamination

Analyses of ground water, soil vapor, soil, and bedrock indicate that VOCs and tritium have been released from the Pit 6 Landfill. Contamination extends to a depth of about 70 feet, and affects the saturated terrace alluvium and shallow bedrock aquifer. No water-supply wells have been affected, nor has any contamination been detected offsite.

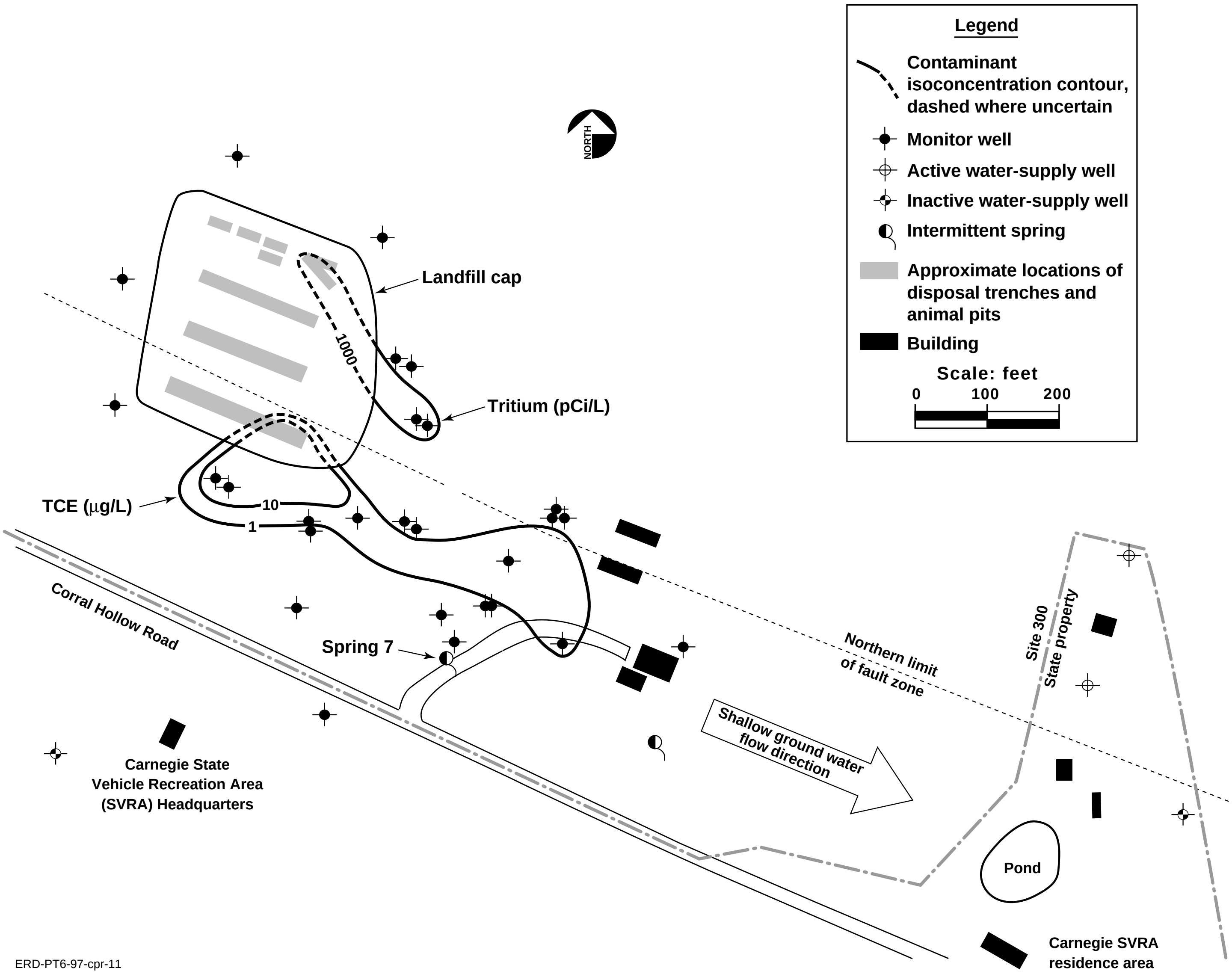
Data indicate that the TCE emanates from the southeastern part of the landfill, possibly from drums placed in trench 3. TCE concentration in ground water has been declining since 1989 when the highest concentration measured was 250 micrograms per liter (µg/L). The maximum concentration of TCE detected in 1997 was 15 µg/L, slightly above the federal and state Maximum Contaminant Level (MCL) of 5 µg/L. Trace (sub-MCL) concentrations of chloroform, *cis*-1,2-dichloroethene, and tetrachloroethene are also present.

The maximum activity of tritium currently detected in ground water is 1,540 pCi/L, well below the MCL of 20,000 pCi/L. Disposal records indicate that shipment cell 55, near the northeastern corner of the landfill, received more than 99% of the tritium buried in the landfill and is the most likely source of the tritium contamination.



TCE concentration in ground water monitor wells at the Pit 6 Landfill.

Nature and Extent of Contamination (cont.)



Distribution of contaminants in ground water (1997).

4. REMEDIATION DESCRIPTION

Primary Technology

The primary remedial technology selected for the Pit 6 Landfill OU is capping. In the summer of 1997, a multi-layer cover was placed over the three trenches and six animal pits in the landfill to isolate the buried waste, prevent future rainwater infiltration, prevent further void space collapse and associated safety hazards, and reduce ground water recharge near the VOC plume. The cap also prevents the potential flux of VOC vapors to the surface. To control surface water, a diversion and drainage system was constructed along the perimeter of the cap.

The contents of the trenches and animal pits will remain in place. Rising ground water inundating the waste is unlikely because the water table historically has been at least 15 feet below the bottom of the waste, and the cap and drainage diversion system will reduce recharge by infiltration. TCE and tritium in ground water will continue to be monitored. Final cleanup standards for ground water will be determined in the forthcoming Site-Wide Record of Decision.

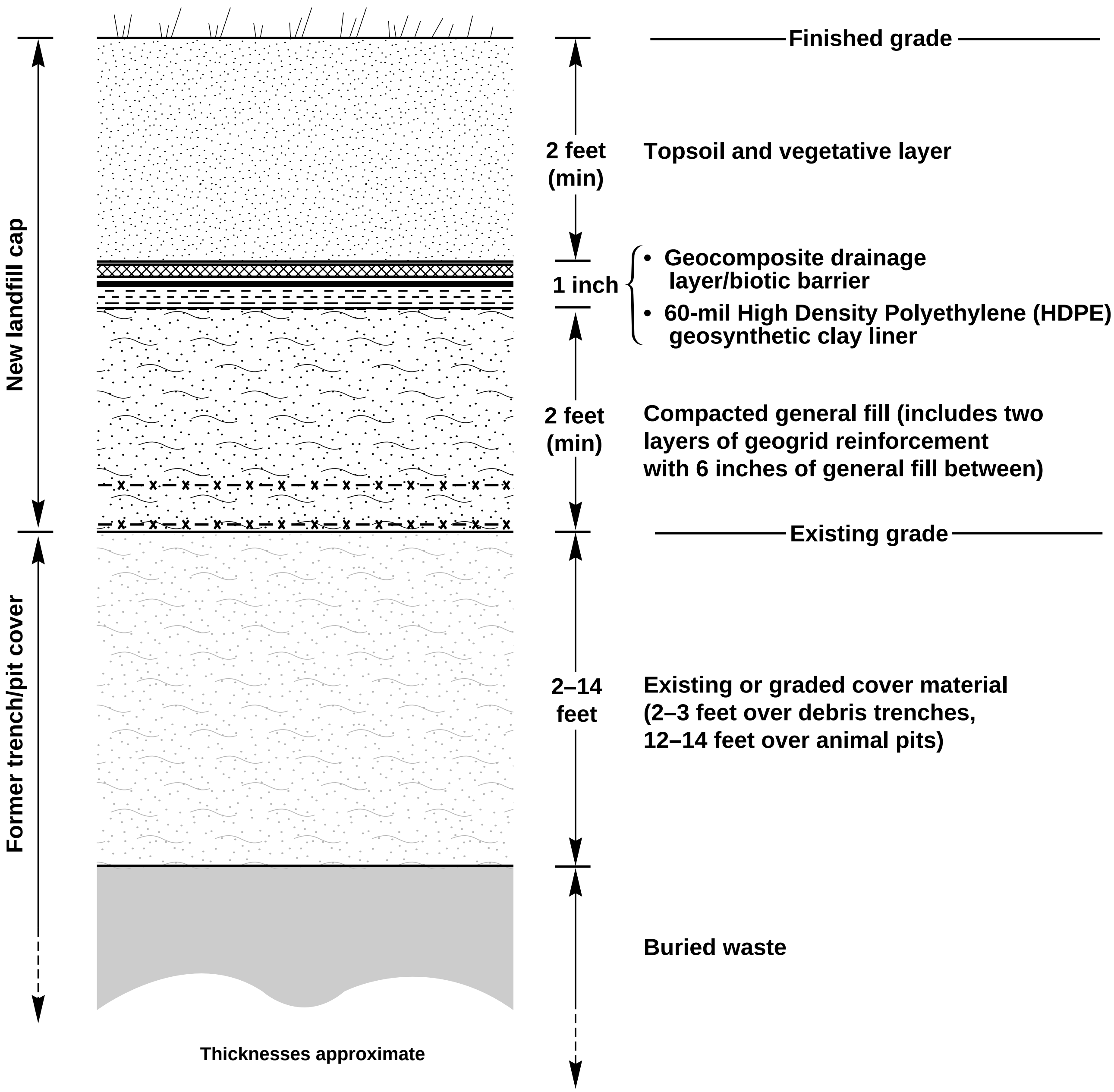
Key Design Criteria

The Pit 6 Landfill cap is about 2.4 acres in size, extending more than 25 feet beyond the perimeter of the buried waste trenches and animal pits. In some areas, the cap was extended farther due to uncertainties in the exact location of the buried waste and to cover areas where VOCs in the subsurface had potential to cause worker inhalation exposure.

The cap consists of several layers, and meets the performance criteria of preventing rainwater infiltration into the buried waste, mitigating potential damage by burrowing animals and vegetation, preventing safety hazards due to potential collapse of void spaces in the buried waste, and mitigating potential flux of VOC vapors through the soil.

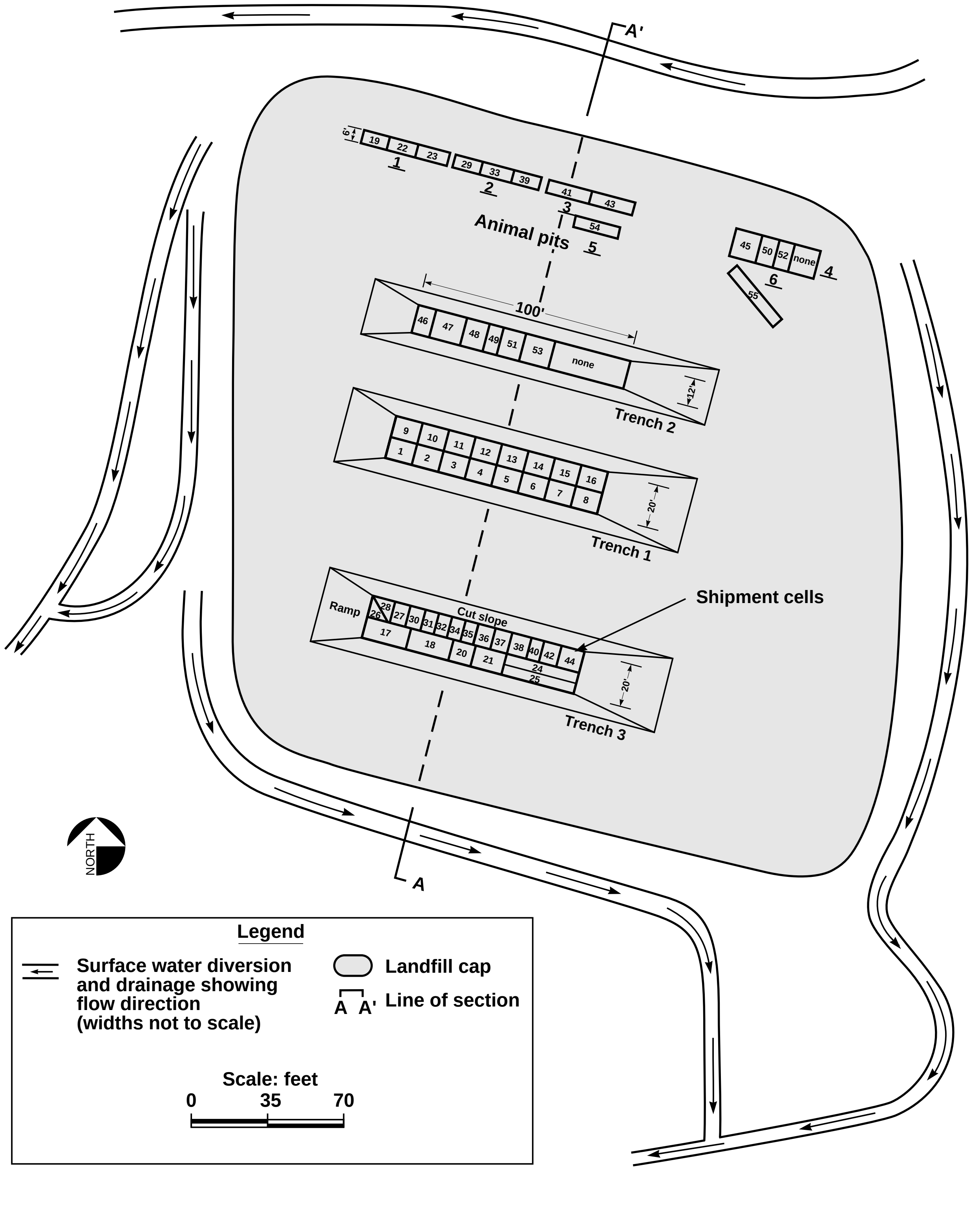
The northern diversion channel is lined with rip-rap and will capture runoff from the slope north of the landfill and divert it to a natural drainage divide to the west. Drainage channels on the east, west, and south sides of the landfill cap are lined with concrete and will collect and drain rainwater that runs off the cap as well as rainwater that has infiltrated through the vegetative layer and drained to the perimeter through the geocomposite drainage layer.

Key Design Criteria (cont.)



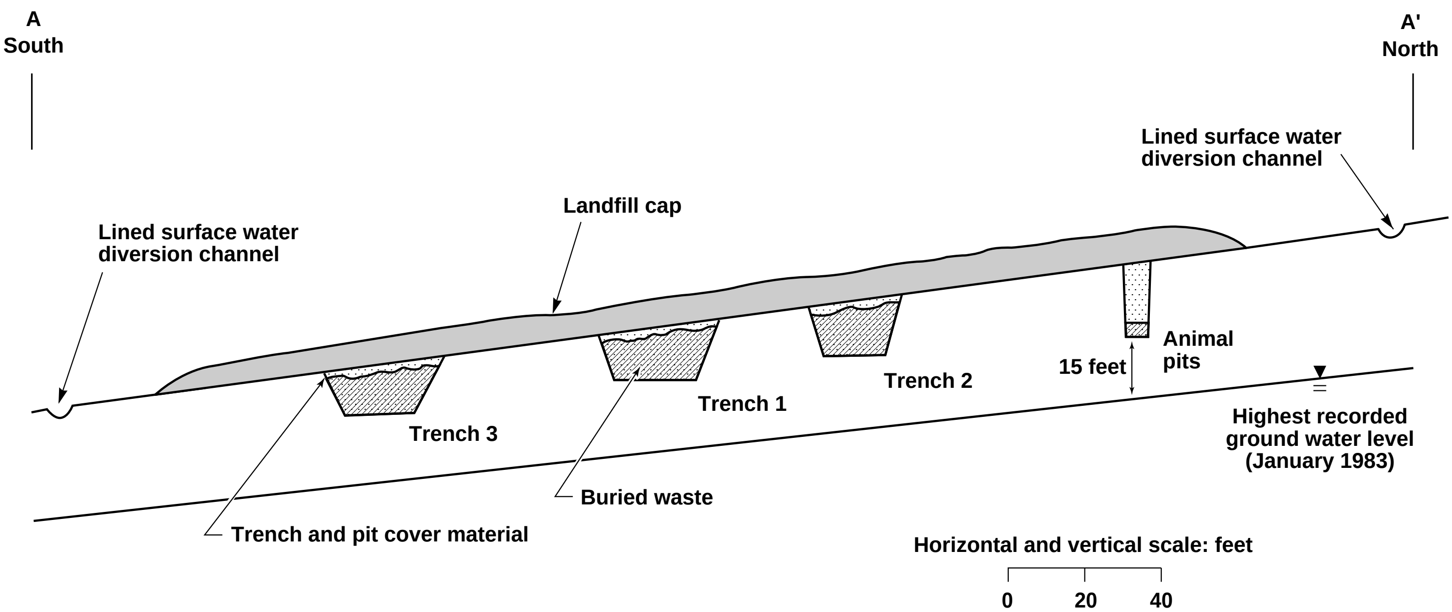
Typical section of the Pit 6 Landfill cap.

Key Design Criteria (cont.)



Pit 6 landfill cap and surface water diversion and drainage system.

Key Design Criteria (cont.)



Cross section of the Pit 6 Landfill.

Pit 6 Landfill liner during installation; view looking south (July 1997).

Key Design Criteria (cont.)

Components of the landfill cap.

Layer (top to bottom)	Description and purpose
Topsoil and vegetative layer	A minimum of 2 feet of native soil to protect underlying liner system. Prevents majority of infiltration by capturing rainwater and allowing evapotranspiration and/or runoff before water reaches the liner. Vegetation minimizes erosion. Grasses selected with root depths that will not impact underlying liner system.
Geocomposite drainage layer/biotic barrier	High-Density Polyethylene (HDPE) netting sandwiched between synthetic filter fabric. High transmissivity material drains infiltrating water to the perimeter of the landfill cap, preventing water from ponding on underlying liner. Material will also serve as a deterrent to burrowing animals.
HDPE/geosynthetic clay liner	60-mil HDPE liner over bonded bentonite clay layer. Very low permeability prevents rainwater infiltration into buried waste. Bentonite clay layer acts as an expansive sealant in the unlikely event of a liner puncture. Liner also prevents potential upward flux of VOC vapor.
General fill	Compacted native soil to provide a level surface for liner placement. Design specifies a thickness of 2 feet to mitigate damage to liner system from potential local earthquakes.
Geogrid reinforcement	HDPE flexible grid material to provide short- and long-term structural support over potential void spaces in the buried waste. Two or three layers (depending on location) separated by 6 inch lifts of general fill. Geogrid reinforcement provides increased safety during and after construction.

5. REMEDIATION PERFORMANCE

Design concern	Performance goals	Performance criteria
Infiltration	Minimize surface water infiltration to prevent leachate generation.	Vegetative/topsoil layer 2 feet thick (minimum) to maximize evapotranspiration. Geocomposite drainage layer prevents ponding of infiltrated rainwater on liner. Combined 60-mil HDPE liner and 0.25-inch-thick geosynthetic clay liner provides a permeability of less than 4×10^{-12} cm/sec.
Subsidence caused by void space collapse in buried waste	Ensure long-term integrity of cap and safety of onsite workers.	Geogrid reinforcement layers used to bridge potential void spaces. Strength of layers capable of supporting loads from new rifle range structure and a 2.5-ton service truck.
Surface water control	Protect cap from storm water run-off and run-on.	Perimeter drainage system including concrete-lined ditches, rip-rap-lined channel, and corrugated metal culverts with capacity for a 24-hour Probable Maximum Precipitation storm event.
Vapor control	Prevent the possible escape of low concentration VOC vapors to the surface to mitigate potential inhalation exposure to onsite workers.	Low permeability liner used to prevent water infiltration also prevents vapor escape. Buried waste will not produce methane so gas buildup not a concern.
Burrowing animals	Prevent damage to liner system by burrowing animals.	Geocomposite drainage layer to deter animals. Periodic inspections to be conducted.
Earthquake damage	Minimize potential for liner integrity compromise as a result of a seismic event that could potentially occur on a fault located about 150 feet south of the landfill.	Used probability assessment to determine Peak Ground Acceleration (PGA) with a 10% chance of being exceeded in 50 years. Determined that 2-foot-thick general fill layer beneath liner is sufficient to prevent damage to liner as a result of 4.4-g PGA.
Post-closure use	Cap must accommodate installation of a new rifle range to replace the one demolished during construction.	An additional geogrid reinforcement layer was placed over a portion of the landfill to bear the load of the rifle range structure.

Monitoring

Post-closure ground water monitoring will include analyses for substances confirmed to have been released from the Pit 6 Landfill debris trenches and animal pits (VOCs and tritium), as well as for those potentially present in the buried waste (beryllium, PCBs, mercury, and radionuclides). Ground water samples will be collected quarterly, and statistical analyses performed on the results. Ground water elevation will also be measured quarterly. The Post-Closure Plan will establish: (1) a Detection Monitoring Program to identify future releases, and (2) a Corrective Action Monitoring Program to assess the performance of the landfill cap. Both programs will be periodically evaluated as part of Site 300 CERCLA Five-Year Reviews.

Risk Reduction

The baseline risk assessment for Pit 6 presented in the Site-Wide Remedial Investigation Report (Webster-Scholten, 1994) concluded that potential exposure to VOCs volatilizing from shallow soil in the vicinity of the rifle range above Pit 6 presented a maximum excess lifetime cancer risk to onsite workers of 5 in 1,000,000 (5×10^{-6}). The landfill cap is designed to mitigate this risk by preventing upward flux of VOCs from the subsurface.

Surface water, when present at spring 7, presents a maximum excess lifetime cancer risk to onsite workers of 4 in 100,000 (4×10^{-5}). This spring has not flowed since the summer of 1992, and no exposure pathway currently exists.

The cap is designed to reduce recharge to the shallow aquifer, and may prevent flow from spring 7 from occurring in the future. If flow resumes and VOC concentrations are detected at levels that pose a risk, contingency measures will be implemented which may include access controls and ground water remediation.

Ground water modeling indicates that there is little possibility of VOCs reaching offsite water supply wells; the nearest are located at the Carnegie State Vehicle Recreational Area, over 800 feet southeast of the Pit 6 ground water plume.

6. REMEDIATION COSTS

Cost elements for the Pit 6 Landfill.

General activity areas (WBS)	WBS second level cost elements (WBS)	Cost items	Costs ($K)	Subtotal ($K)
Preliminary/ Preconstruction Activities (32)	• RI/FS (32.02)	• Feasibility Study (Engineering Evaluation/Cost Analysis) and related work - Alternative evaluation - Conceptual design - Ground water extraction modeling - Document preparation - Regulatory interface	844	1,401
		• Addendum to EE/CA	47	
		• Public Workshop/Action Memorandum	65	
	• Remedial Design (32.03)	• Landfill Cap Design - Title I design document - Title II design document	398	
		• Post-closure plan	47	
Construction Activities (33)	• Mobilization and Preparatory Work (33.01)	• Contractor selection/site preparation - RFP distribution/contractor selection - Controlled burn of vegetation - Security coordination - Construction site fencing installation - Archaeological and ecological clearances - Coordination with other facility operations	53	1,078
	• Site Work (33.03)	• Removal Action Construction: - Demolish rifle range - Construct landfill cap	698	
		• Construction quality assurance and report	89	
		• Construction management	238	
Post-Construction Operations and Maintenance: Removal Action (34)	• Monitoring, Sampling, Testing, and Analysis (34.02)	• Landfill Operation and Maintenance (30 yrs in present-worth dollars) - Inspections, surveys, reporting - Maintenance and repairs	121	1,612
		• Ground water monitoring (30 yrs in present-worth dollars) - Sampling - Analysis	1,491	
		Total Pit 6 Landfill Removal Action		$4,091K

7. REGULATORY ISSUES

All remediation activities are carried out under CERCLA and in accordance with the Site 300 Federal Facility Agreement. Regulatory agencies overseeing the Pit 6 OU include the U.S. EPA, California Regional Water Quality Control Board–Central Valley Region, and California Department of Toxic Substances Control.

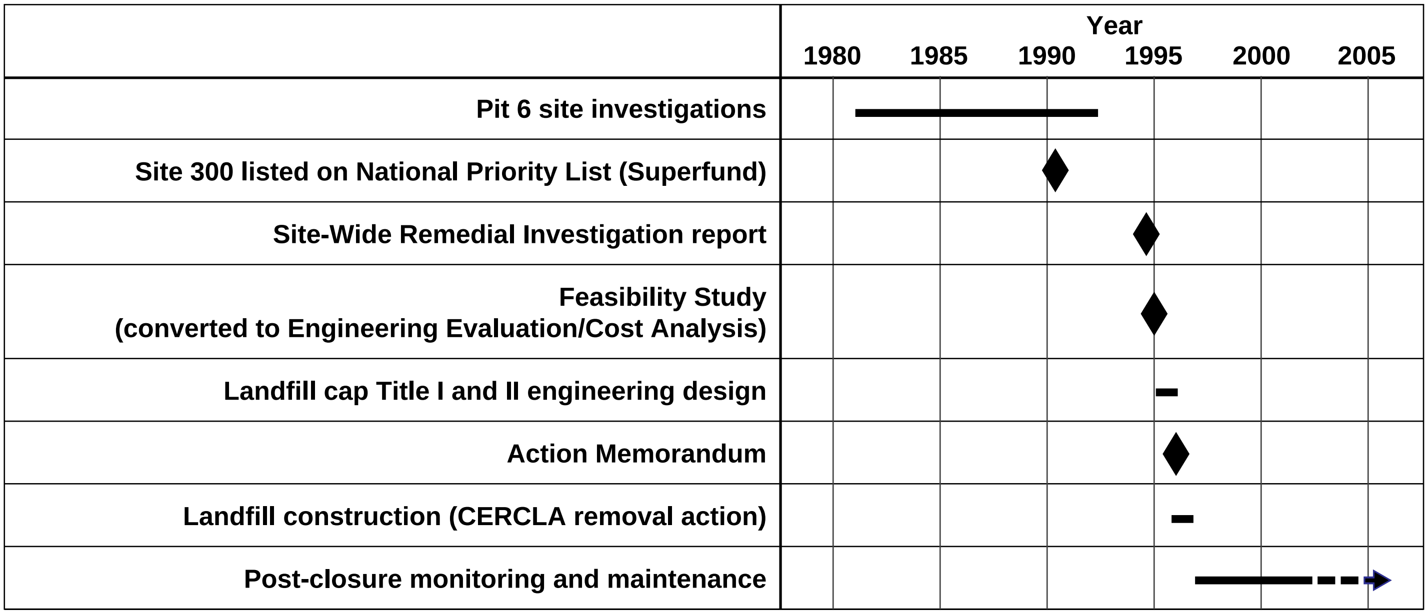
As part of the DOE/LLNL program of streamlining the CERCLA process, the landfill capping was conducted as a non-time-critical removal action. Federal and State regulatory agencies approved of this approach, which resulted in accelerating the project schedule by a full year. DOE authorized capping to proceed through an Action Memorandum.

Final ground water cleanup standards for the OU will be established in the forthcoming Site-Wide Record of Decision. If natural attenuation of the VOC plume continues, it is possible that no further action will be necessary. However, if VOC concentrations do not decline to meet cleanup standards, or if plume migration accelerates, active measures such as ground water extraction and treatment may be required.

CERCLA compliance criteria analysis for the Pit 6 Landfill removal action.

Objective/criteria	Summary of analysis
Overall protection of human health and the environment	Landfill cap: (1) reduces possibility of future releases from the buried waste, (2) prevents any potential direct exposure to the waste, (3) removes potential safety hazard from subsidence, and (4) reduces inhalation risk from VOCs in subsurface soils and exposure potential for sensitive ground-dwelling species.
Compliance with Applicable or Relevant and Appropriate Requirements (ARARs)	Landfill cap construction meets all ARARs, but capping alone may not meet State requirements for protection of beneficial uses of ground water.
Long-term effectiveness and permanence	Landfill cap reduces possibility of future releases by preventing surface water infiltration, prevents direct exposure to waste, and reduces potential inhalation exposure to VOCs in subsurface soil. May not protect all beneficial uses of ground water. Cap requires inspection and maintenance to ensure integrity and is subject to damage by rain, erosion, settlement, and seismic activity. Fence, signs, and site access restrictions will manage inhalation health risks at spring 7, if necessary.
Reduction in toxicity, mobility, and volume	Landfill cap reduces mobility of waste by preventing surface water infiltration. Toxicity and volume of buried waste and contaminated ground water are not reduced.
Short-term effectiveness	Safety monitoring and construction procedures minimize possible releases and worker exposure during landfill cap construction and monitoring. Human exposure and contaminant release could occur from cave-ins, rupture of waste containers, and dust generated during cap construction.
Implementability	Technically and administratively implementable. Equipment and materials for cap readily available. Landfill cap grading and compacting activities could cause additional releases by disturbing buried containers. Landfill cap construction requires demolition and replacement of rifle range.

8. SCHEDULE



9. OBSERVATIONS AND LESSONS LEARNED

Implementation Considerations

Implementing landfill cap design and construction as a non-time-critical removal action reduced the number and size of required regulatory documents needed for approval and accelerated the project by one full year. A major component of schedule acceleration was paralleling design work with regulatory and community input and approval to reduce review time and edits.

It is important to provide bidding contractors sufficient time to prepare competitive bids, essentially because there are a limited number of qualified geosynthetic installation contractors available. Due to tight scheduling, there was a a short bid submittal time frame for the Pit 6 landfill cap (about two weeks) that may have reduced the number of bids submitted and inhibited competition for the work.

The successful construction contractor's bid was within allowable cost tolerances, but all other bids were significantly higher. This may have been a result of bidders not having been allowed sufficient time to analyze specifications in detail, with the effect of added contingencies being included by bidders.

The landfill cap design specifications were required to accommodate constructing and operating a new rifle range on top of the cap. The geogrid structural reinforcement layer, combined with restrictions on using motor vehicles on the cap, will minimize the potential for damage caused by the collapse of void spaces in the buried waste.

Technology Advancements

Selectively substituting geosynthetic materials for natural materials saved over $500,000. Using a HDPE/geosynthetic clay liner in place of one to two feet of clay virtually eliminated concerns over possible desiccation cracks, low moisture content, and compaction of the impermeable liner during hot weather construction. Additionally, installation was much faster and quality assurance was more controllable.

Over $300,000 of these savings were realized by substituting a geocomposite drainage layer for a conventional cobble layer to protect the underlying liner from burrowing animals. Weight over the buried waste was reduced and overall cover height was kept to a minimum. However, data are limited on the performance of the geocomposite drainage layer to deter burrowing animals. A geocomposite drainage layer has been used successfully at other sites, but careful inspections will be conducted to ensure continued integrity of the cap.

Installing the HDPE/geosynthetic clay liner (July 1997).

10. REFERENCES

Berry, T. *(1996), Addendum to the Pit 6 Engineering Evaluation/Cost Analysis Lawrence Livermore National Laboratory Site 300*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-113861 Add).

Berry, T. (1997), *Action Memorandum for the Pit 6 Landfill Operable Unit Removal Action at Lawrence Livermore National Laboratory Site 300,* Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-126418).

Devany, R., R. Landgraf, and T. Berry (1994), *Final Feasibility Study for the Pit 6 Operable Unit Livermore National Laboratory Site 300,* Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-113861). Note: In August 1995, this document was accepted as an Engineering Evaluation/Cost Analysis.

Webster-Scholten, C. P. (Ed.) (1994), *Final Site-Wide Remedial Investigation Report, Lawrence Livermore National Laboratory Site 300,* Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-108131).

11. VALIDATION

Signatories:

"This analysis accurately reflects the current performance and projected costs of the remediation."

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12. ACKNOWLEDGMENTS

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